

## AGC circuit

## Background of the invention

The invention relates to an AGC circuit comprising a digitally controlled amplifier being provided with a gain control loop including a level detector, a threshold circuit and a digital gain control signal generator being coupled to a gain control input of the  
5 digitally controlled amplifier for supplying thereto a digital gain control signal as well as to a DAB receiver comprising such an AGC circuit. An AGC circuit of this kind is on itself widely known, e.g. from US patent no. 4 774 474.

The known AGC provides for an automatic digital gain setting of the digitally  
10 controlled amplifier, such that the output signal is stabilized at a particular predetermined level. The digitally controlled amplifier may comprise a number of gain stages in series and/or parallel, which can be switched off and on, dependent on the gain setting required to stabilize the output signal level. Each gain stage can be optimized for linearity, signal to noise ratio and gain within its working area. This allows to optimize the digitally controlled  
15 amplifier at small input signal amplitudes for proper signal to noise ratio at high gain factor. The digitally controlled amplifier can be optimized at large input signal amplitudes for accurate linearity and low gain factor.

However, small deviations around the switching levels of the known digital gain control signal give rise to repeated switching between two gain settings. This modulates  
20 the output signal of the digitally controlled amplifier, therewith causing an increase in the bit error rate, which may cause e.g. audible distortions to occur.

## Summary of the invention

25 Therefore, it is an object of the invention to stabilize the gain setting and to avoid said repeated switching between gain settings.

An AGC circuit comprising a digitally controlled amplifier being provided with a gain control loop including a level detector, a threshold circuit and a digital gain

control signal generator being coupled to a gain control input of the digitally controlled amplifier for supplying thereto a digital gain control signal, according to the invention is therefore characterized by a continuously controlled amplifier being coupled between an output of the digitally controlled amplifier and the level detector, an output of the level  
5 detector being coupled to a gain control input of the continuously controlled amplifier for supplying thereto an continuous gain control signal, the gain variation range of the continuously controlled amplifier at least corresponding to the gain step variation of the digitally controlled amplifier at an incremental step of said digital gain control signal.

By applying the measure according to the invention, a course gain setting is  
10 obtained with the digitally controlled amplifier, whereas a continuous gain setting is obtained with the continuously controlled amplifier. By choosing the gain variation range of the continuously controlled amplifier to correspond at least to the gain step variation of the digitally controlled amplifier at an incremental step of said digital gain control signal repeated switching between gain settings are avoided.

15 To stabilize the gain loop against oscillation preferably a loop filter is being coupled between the output of the level detector on the one hand and the gain control input of the continuously controlled amplifier and the threshold circuit on the other hand.

A further preferred embodiment of the AGC circuit allowing cost-effective implementation is characterized in that the threshold circuit comprises first and second  
20 comparators for comparing the output signal of the level detector with positive and negative threshold levels around a zero level for initiating the digital gain control signal generator for a stepwise variation of the gain of the digitally controlled amplifier.

Preferably the digital gain control signal generator comprises a pulse generator coupled to a clock-signal input of a digital counter for supplying a clock-signal thereto, the  
25 threshold circuit including a third comparator for comparing the output signal of the level detector with a zero level, an output of the third comparator being coupled to an up/down input of the counter.

Another preferred embodiment of the AGC circuit according to the invention is characterized in that the gain variation range of the continuously controlled amplifier  
30 caused defined by the range of the continuous gain control signal between the negative and positive threshold levels, corresponds at least to a gain variation of the digitally controlled amplifier exceeding the value for one incremental step, preferably over two or more consecutive incremental steps, of said digital gain control signal. This further secures the prevention of repeated switching between two gain settings.

A receiver for digitally modulated signals, for example a DAB receiver, comprising an AGC circuit according to the invention is characterized by said digitally controlled amplifier being coupled between an RF input filter and a phase quadrature mixer stage, phase quadrature outputs thereof being coupled through frequency selective means to a pair of phase quadrature continuously controlled amplifiers, this pair of phase quadrature continuously controlled amplifiers being coupled through to a pair of phase quadrature analogue to digital converters to said level detector.

#### Brief description of the drawings

The invention will now be described with reference to the accompanying drawings, in which:

Figure 1 shows a preferred embodiment of an AGC circuit according to the invention;

Figure 2 shows a preferred embodiment of a DAB receiver using an AGC circuit according to the invention.

The figures are not drawn to scale. In general, like reference numerals refer to like parts.

#### Detailed description of preferred embodiments

Figure 1 shows a preferred embodiment of an AGC circuit according to the invention comprising a digitally controlled amplifier DCA followed by a continuously controlled amplifier VCA, an output thereof being coupled to a gain control loop including subsequently a level detector LD and a loop filter LF. An output of the loop filter LF is coupled to a gain control input of the continuously controlled amplifier VCA for supplying thereto an continuous gain control signal, as well as to a threshold circuit T. A first output TO1 of the threshold circuit T is coupled via a pulse generator PG to a clock signal input CI of a digital counter C and a second output TO2 of the threshold circuit T is coupled to an up/down control input U/D of said digital counter C. The digital counter C supplies a digital gain control signal to the digitally controlled amplifier DCA. The pulse generator PG and said digital counter C therewith function as a digital gain control signal generator.

The gain variation range of the continuously controlled amplifier VCA corresponds at least to the gain step variation of the digitally controlled amplifier DCA at an incremental step of said digital gain control signal.

The threshold circuit T comprises first to third comparators T1 – T3, the first and second comparators T1 and T2 are used to compare the output signal of the loop filter LF respectively with positive and negative threshold levels  $V_{tp}$  and  $V_{tn}$  around a zero level  $V_0$ , the third comparator T3 is used to compare the output signal of the level detector with a zero level. Therefore the first to third comparators T1 – T3 are each provided with positive and negative inputs, said positive inputs being coupled in common to the output of the loop filter LF, the negative inputs of the first and second comparators T1 and T2 being coupled through respective positive and negative threshold voltage sources  $V_{tp} = +\Delta V$  and  $V_{tn} = -\Delta V$  to mass and the negative input of the third comparator T3 being coupled through a zero voltage source (current source) to mass. Outputs of the first and second comparators T1 and T2 are coupled through an OR gate to the first output TO1 of the threshold circuit T, an output of the third comparator T3 being coupled via the second output TO2 of the threshold circuit T to the up/down control input U/D of the digital counter C.

If the output signal of the loop filter LF increases above the positive threshold level  $V_{tp}$ , then the first comparator T1 causes the pulse generator GP to generate and supply a clock pulse to the counter C. If the output signal of the loop filter LF decreases below the negative threshold level  $V_{tn}$ , then the second comparator T2 causes the pulse generator GP to generate and supply a clock pulse to the counter C. The third comparator T3 controls the digital counter C to count down at the reception of a clock pulse from the pulse generator PG when the output signal of the loop filter LF increases above the positive threshold level  $V_{tp}$ . The third comparator T3 controls the digital counter C to count up at the reception of a clock pulse from the pulse generator PG when the output signal of the loop filter LF decreases below the positive threshold level  $V_{tn}$ . The range between positive and negative threshold levels  $V_{tp}$  and  $V_{tn}$  define the range in which the output signal of the loop filter LF, i.e. the continuous gain control signal for the continuously controlled amplifier VCA, may vary without for changing the gain setting of the digitally controlled amplifier DCA.

By choosing in accordance with the invention, the gain variation range of the continuously controlled amplifier VCA to correspond at least to the gain step variation of the digitally controlled amplifier DGA at an incremental step of said digital gain control signal, i.e. the gain increase occurring in the digitally controlled amplifier DGA at an up-count of

one clock-pulse and/or the gain decrease occurring at a down-count of one clock-pulse, astable gain settings of the digitally controlled amplifier DGA are avoided.

Preferably the gain variation range of the continuously controlled amplifier VCA is chosen to correspond to a gain variation of the digitally controlled amplifier DGA exceeding the value for one incremental step, preferably over two or more incremental steps, of said digital gain control signal. This further secures the avoidance of repeated switching of the gain of the digitally controlled amplifier DGA between two gain settings.

However, overshoot in the gain control of the digitally controlled amplifier DGA by superposition of subsequent gain step variations may occur, when the time between two consecutive clock-pulses decreases below a certain value, which is defined by the time-constant of the AGC loop. This can be prevented by appropriately limiting the speed of the pulse generator PG.

Furthermore, the time-constant of the loop filter LF is chosen sufficiently large to prevent regenerative feedback of the gain control signal of the continuously controlled amplifier VCA.

Figure 2 shows a preferred embodiment of a DAB receiver using an AGC circuit according to the invention, comprising the above mentioned digitally controlled amplifier DCA being coupled between an RF input filter RF and a phase quadrature mixer stage 1. Phase quadrature outputs of the phase quadrature mixer stage 1 are coupled through phase quadrature frequency selective means 3 to a continuously controlled phase quadrature amplifier VCA. This continuously controlled phase quadrature amplifier VCA is coupled through a pair of blocking capacitors 4 to a phase quadrature analogue to digital converter 5. Outputs of the phase quadrature analogue to digital converter 5 are coupled through a phase quadrature decimation filter 8 to a CORDIC mixer 8, followed by a phase quadrature DAB channel filter 9. Phase quadrature outputs of the phase quadrature DAB channel filter 9 are coupled through an AGC controlled phase quadrature amplifier 10 to phase quadrature inputs of a Fast Fourier Transform device 12, a signal output thereof supplying a wanted base-band DAB modulation signal, a first control output thereof supplying a frequency control signal to the CORDIC demodulator 8 and a second control output thereof supplying a time synchronization signal to a clock-signal generator 6. The clock-signal generator 6 supplies a clock-signal to the phase quadrature analogue to digital converter 5.

The signal processing of a DAB receiver as provided by the circuitry 1-12 is on itself known e.g. from US patent no. 6,021,165. For a proper understanding of the present

invention, detailed knowledge thereof is not required. For this reason no further details with regard to said DAB receiver circuitry will be given.

In the DAB receiver as shown in this Figure 2, the digitally controlled amplifier DCA functions as a broadband amplifier, whereas the continuously controlled phase quadrature amplifier VCA is functioning as a narrow band amplifier. The level of the phase quadrature output signal of the continuously controlled phase quadrature amplifier VCA is detected at two specific locations in the phase quadrature receiver signal path, namely at the output of the phase quadrature frequency selective means 9 and at an output of the phase quadrature analogue to digital converter 5. The level detector LD combines these two level informations into a single gain control signal reflecting properly the level of the phase quadrature output signal of the continuously controlled phase quadrature amplifier VCA.

Preferably the AGC circuit according to the invention is applied in receivers for digitally modulated signals, like DAB, GSM, DCS, UMTS, DECT, Bluetooth etc, which are relatively insensitive to level changes by steps during reception.

The AGC circuit used in the DAB receiver as shown corresponds in its operation with the one described under figure 1.

It should be apparent that various changes may be made in the present invention as presented in figures 1 and 2 without departing from the spirit and scope of the invention.